6. CLOUDINESS AND THE RADIATION BUDGET

6.1 OBSERVED CLOUD CHARACTERISTICS

At present, the interrelationships between clouds and the ERBSS radiation budget measurements are only qualitatively known. In order to quantify these relationships, independent concurrent data of physical cloud characteristics are required. These data include, but are not necessarily limited to, the characteristics listed below.

Cloud Field Descriptors:

(a) cloud amount

(b) cloud height

(c) cloud-top texture

(d) height-width ratios

(e) microphysical properties

(f) total water content

(g) liquid/ice water content

(h) radiative characteristics

(i) cloud base altitude

Items (a) to (c) may be determined from satellite instrumentation although different techniques may yield different results. Currently there is insufficient knowledge about which definition of a specific variable or which technique is best for the study of cloud-radiation budget interrelationships. Items (d) to (h) have rigorous definitions and may be observed directly or inferred from measurements from satellites, aircraft, or the surface. Except for relatively thin clouds, item (i) probably cannot be measured from satellites. In order to obtain large statistical samples of cloud base height data, some continuously operating surface lidar installations should be established.

6.1.1 Findings

At the present time definitions of cloud amount, cloud height, cloud emissivity and cloud reflectivity deduced from satellite data are so interrelated that it is difficult to select a "best" definition for consistent use in relating observed cloud characteristics to model-predicted cloud characteristics. Cloud base information is conspicuously absent from present data archives but is critical to simulation of accurate radiative flux divergence estimates. ERBSS data, because of the large field of view of the scanning radiometer, may not be useful for inference of cloud characteristics.

6.1.2 Recommendations

It is recommended that *a contingent of climate modelers and satellite meteorologists define specifically a set of cloud field variables which will be both observable and satisfy model verification requirements.* It is also recommended that *consideration be given to establishment of several continuous operating vertical pointing surface lidars to specifically gather cloud base data statistics.*

6.2 EXTENDED CLOUDINESS AND RADIATION EXPERIMENT

In several recent forums (Joint Organizing Committee WMO, United States Climate Dynamics Plan, NASA 1978 Program Plans) the need for a comprehensive program to investigate the role that clouds play in modulating the Earth's radiation budget has been stated.

Climate has been targeted as the principal meteorological area of application of this knowledge by these forums. Although climate connotes a certain macroscale perspective, the basic building blocks of our understanding about how, when, where and why clouds interact with the radiation field will be deduced from researches dealing with specific physical-dynamic problems. The Extended Cloudiness and Radiation Experiment (ECARE) is an excellent example of an attempt to assemble many of the pieces of information which will ultimately be applied to the climate cloud-radiation problem.

The principal goals of the ECARE are threefold. The first goal is to establish an understanding of the physical processes both responsible for and associated with the formation, persistence, and dissipation of extended fields of cloudiness. This physical understanding is critical to an adequate implementation of extended cloud field radiative effects in climate models. The second goal of the experiment is to observe the variability of cloud field properties on both small and large time and space scales. The cloud field properties essential to this component include microphysical characteristics, temporal and spatial extents, height-width ratios, cloud-top heights, and base heights and radiative characteristics, to name a few. The third goal of ECARE is to relate average cloud characteristics and their variability to both independent and model predictive variables. This final step will provide the tools with which to assess the role of clouds and radiation in climate.

The ECARE is a very ambitious program requiring participation of both small-scale and large-scale modelers and observations of dynamic, thermodynamic, microphysical and radiative characteristics associated with extended cloudiness fields. These observations will be collected from a diverse array of platforms including satellites, aircraft, rawinsonde balloons and surface installations.

Because of the extensive set of observational data required by ECARE and since ECARE is so closely linked to an adequate understanding of the Earth's radiation budget and its variability on various time and space scales, it is recommended that the *appropriate Federal agencies (National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF)) fully support ECARE.*

6.3 EARTH RADIATION BUDGET CONCERNS

The ERBSS scanning radiometer is the only component of the ERBSS system lending itself to regional radiation budget observations. In order to convert an observed radiance value into an irradiance estimate, one must assume an angular distribution function of the radiance field. The multiplicity of angular distribution functions from both fields of small clouds and extended horizontal clouds makes selection of an appropriate distribution function exceedingly difficult.

6.3.1 Findings

The relationship between the angular distribution function of both reflected solar power and emitted infrared power from broken cloud fields is inadequately known to confidently use scanning radiometer type data for regional energy budget studies.

Broken cloud field reflectance properties are dependent upon solar zenith angle; however, the variability of this dependence from one cloud population to another is not adequately known. This suggests that regional radiation budgets over areas of broken clouds may suffer from a lack of understanding of the diurnal variation of the reflected solar irradiance.

The single non-Sunsynchronous satellite does not eliminate completely the diurnal ambiguity created by the two Sun-synchronous TIROS N orbits. This affects both the scanning radiometer and wide field of view radiometer. A study of optimal local times for the Sun-synchronous polar orbiters making radiation budget observations is called for in an attempt to minimize diurnal biases.

6.3.2 Recommendations

In order to reduce the uncertainty of the appropriate angular distribution function to use in the scanning radiometer radiance to irradiance conversion, it is recommended that *serious consideration be given to either modifying the cross track scan mode or introducing a second scanner so that regional elements could be observed on the same orbit from more than a one angle perspective.*

In order to facilitate physical interpretation of changes in regional radiation budgets and to better match climate model calculations, it is recommended that *a second scanning radiometer short wave channel with a limited spectral bandpass for the interval* $\lambda < 0.7\ \mu m$ *be considered.*

6.4 ARCHIVAL AND AVAILABILITY OF METEOROLOGICAL SATELLITE DATA

Satellite radiation budget data and complementary satellite spectral radiance and image data will be essential to understanding cloud-radiation-climate interactions. Massive amounts of this quantitative information are to be collected by ERBSS and other meteorological satellites. Critical questions which arise concern how much and what data should be archived.

Besides the archive question the massive amounts of data dictate a realistic approach for making data accessible to the scientific community.

6.4.1 Findings

Since staggering amounts of meteorological satellite data will be acquired during the next decade, an archival plan must be formulated so that critical ERBSS complementary data are not lost. Two tactics seem plausible in the 1980 - 1990 time frame. One, rely on state-of-the-art mass storage devices and record virtually all data transmitted by the meteorological satellite systems. During the coming decade this may be feasible for the first time. A second tactic is to *a priori* define the required archival data sets based upon defined needs, thereby reducing the archive to a subset(s) of the total possible data base.

User access to the satellite data archive or subsets thereof is as important as the existence of the archive itself. This access must not just exist but be made as easy as possible.

6.4.2 Recommendations

It is recommended that *criteria for selecting basic data sets of meteorological satellite data for archival must be established. These criteria with the use of new mass storage devices must provide assurances that data required to understand the cloud-radiation-climate interactions are not being lost from neglecting to archive the data.*

In order to insure user access to ERBSS and complementary meteorological satellite data, it is also recommended that *criteria be developed to define secondary data sets which will be more manageable for the scientific user. These data sets may be statistical summaries over given geographical or temporal regimes, or a collation of multiple sensor/satellite information over common geographical, time, or phenomenological elements.*